

A dual description of decoherence in deSitter space

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Motivation

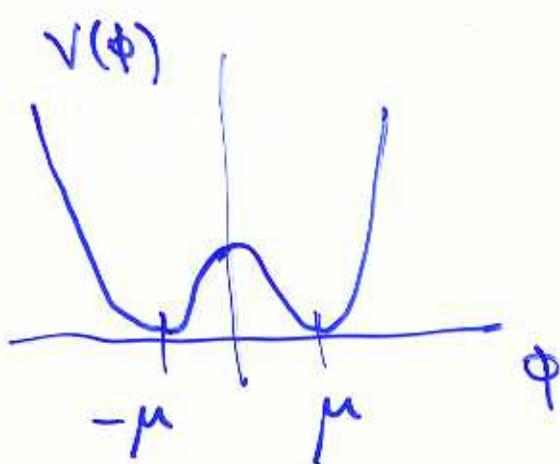
An observer in dS space can set up
a Rabi oscillation experiment.

Will he see any oscillations?

$|L\rangle, |R\rangle$ states :

$$P(t) = P_L(t) - P_R(t) = ?$$

Two-level system in dS



$$\mu > H$$

super-Hubble bubble
will expand

Thin-wall limit :

$$ds_{in}^2 = -(1-r^2) dt^2 + \frac{dr^2}{1-r^2} + r^2 d\Omega^2$$

$$ds_{out}^2 = -f(r) dt'^2 + \frac{dr'^2}{f(r)} + r'^2 d\Omega^2$$

$$f(r) = 1 - r'^2 - \frac{2kE}{r'}$$

From the junction conditions

$$E = M \left(r^2 + (1-r^2)^{1/2} \right) - k \frac{M^2}{2r} \stackrel{\Sigma 4\pi G r^2}{\sim}$$

Vacuum tunneling : $E=0$, $r_c = \frac{1}{1+4\alpha^2 k^2 \delta^2}$

(Results match those from instanton calculus.)

Decoherence in dS

Two (constrained) histories:

$$U_1(t_1, t_2)$$

$$|L\rangle \rightarrow |L\rangle$$

$$U_2(t_1, t_2; \Delta t)$$

$$|L\rangle \xrightarrow{\Delta t} |R\rangle \rightarrow |L\rangle$$

$$|\langle L | U_2^\dagger U_1 | L \rangle|^2 = e^{-\frac{1}{2} V_{\text{comov}} w_0 (\Delta \phi_{\text{conf}})^2}$$

$$w_0 \approx \sqrt{2} \mu a(\eta)$$

$$\Delta \phi_{\text{conf}} \approx 2 \mu a(\eta)$$

$$\text{As a result, } P(t) = P_L - P_R = e^{-\Gamma t}$$

- tunneling completely incoherent

Dual description

$$ds_E^2 = (1-r^2) d\tau^2 + \frac{dr^2}{1-r^2} + r^2 d\Omega^2$$

An "environment" on a sphere of radius $r_0 \approx 1$:

$$ds_0^2 = (1-r_0^2) d\tau^2 + r_0^2 d\Omega^2$$

$$T_0 = \frac{2\pi}{\sqrt{1-r_0^2}}$$

System-environment interaction:

$$S_{\text{int}} = \int d\tau d\Omega \Phi(\Omega, \tau) U(\Omega, \tau)$$

\curvearrowleft

$$\Phi(r_0, \Omega, \tau)$$

Quadratic effective action for Φ :

$$S[\Phi] \sim \int d\tau d\tau' d\Omega d\Omega' \underbrace{\Phi_{\Omega, \tau} \Phi_{\Omega', \tau'}}_{\text{correlator of the boundary theory}} \langle U_{\Omega, \tau} U_{\Omega', \tau'} \rangle$$

Properties of the boundary via "AdS/CFT"

$$\frac{1}{r^2} \partial_r [r^2 (1-r^2) \partial_r \phi] - \frac{\partial_r^2 \phi}{r^2} + \frac{\partial_\tau^2 \phi}{1-r^2} - M^2 \phi = 0$$

"Standing waves": $\phi(r, \Omega, \tau) = \Phi_{nlm}(r) Y_{lm}(\Omega) e^{i\omega \tau}$

At $x = \sqrt{1-r^2} \gg l$ and $l \ll R = r_0 / \sqrt{1-r_0^2}$:

$$\Phi_{nlm}(x) \sim \begin{cases} \left(\frac{x}{R}\right)^{nl} \Phi_{nlm}, & n \neq 0 \\ \frac{\ln x}{\ln R} \Phi_{0lm}, & n = 0 \end{cases}$$

$$S[\Xi] \sim \sum_{nlm} |n| |\Phi_{nlm}|^2$$

$$\delta(\Omega - \Omega') \frac{1}{(\tau - \tau')^2}$$

"AdS/CFT": $\langle \psi_{nlm} \psi_{nlm}^+ \rangle \sim |n|$

$$G_{nlm}^R(\omega) \sim i\omega \quad (\text{Ohmic})$$

$$\omega_{min} \sim \frac{\hbar^2}{T_0}$$

Decoherence in the dual description

$$\langle L | U_2^+(t_1, t_2; \omega) U_1(t_1, t_2) | L \rangle \sim \bar{\epsilon}^{-Q}$$

$$\text{On } \sum_{lm} \left| \Delta \tilde{\Phi}_{lm} \right|^2 \int_{\omega_{\min}}^{\omega_{\max}} \frac{d\omega}{\omega^2} \text{Im } G_{lm}^R(\omega) (1 - \cos \omega t) \coth \frac{\omega}{2T_0}$$

Thermal dissipation, $T_0 \sim R \sim M_{Pl}$:

$$Q_{lim} \propto M_{Pl}/\omega_{\min} \sim \frac{M_{Pl}^2}{\mu^2}$$

("number of degrees of freedom")

Conclusions

1. AdS-CFT-like correspondence for dS produces reasonable (Ohmic) correlators in the boundary theory. Cf. viscosities.
2. The large decoherence for two-level systems in dS is reproduced, up to expected corrections.